Introduction to Laser Material Processing

Outline

- Contact details
- Course objectives
- Introductory remarks
- Grading policy
- Intro to laser material processing

Contact Details

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  - Tel: 7507
  - Off. Hrs. (Prof. Singh): Fridays 3.25-5 p.m. in Machine Tools Lab
  - Also by appointment
  - Lecture notes will be posted on moodle
  - On website: http://www.me.iitb.ac.in/~ramesh/courses/ME677/me677.html

Focus and Objectives of Course

- Introduction to the practical applications of lasers.
- Developing insight into the physical phenomenon of laser-matter interaction.
- Development of first order mathematical descriptions for select laser processes.
- Understand the capabilities and limitations of various laser processes.
- Apply this knowledge to process selection, design for manufacturing and quality control.
- Encourage hands-on Project.

Introductory Remarks

- See second page of syllabus
  - Homework
  - Exams
  - Honor code

Grading Policy

• Assignments (4)	15%
• Quizzes	10%
• Midterm	25%
• Project	20%
• End semester exam	30%
• Total	100 %

Course Summary

- Focus on:
  - Physical principles and analysis of process
  - Process Capabilities
- Teamwork will be encouraged
  - Homework
  - Project

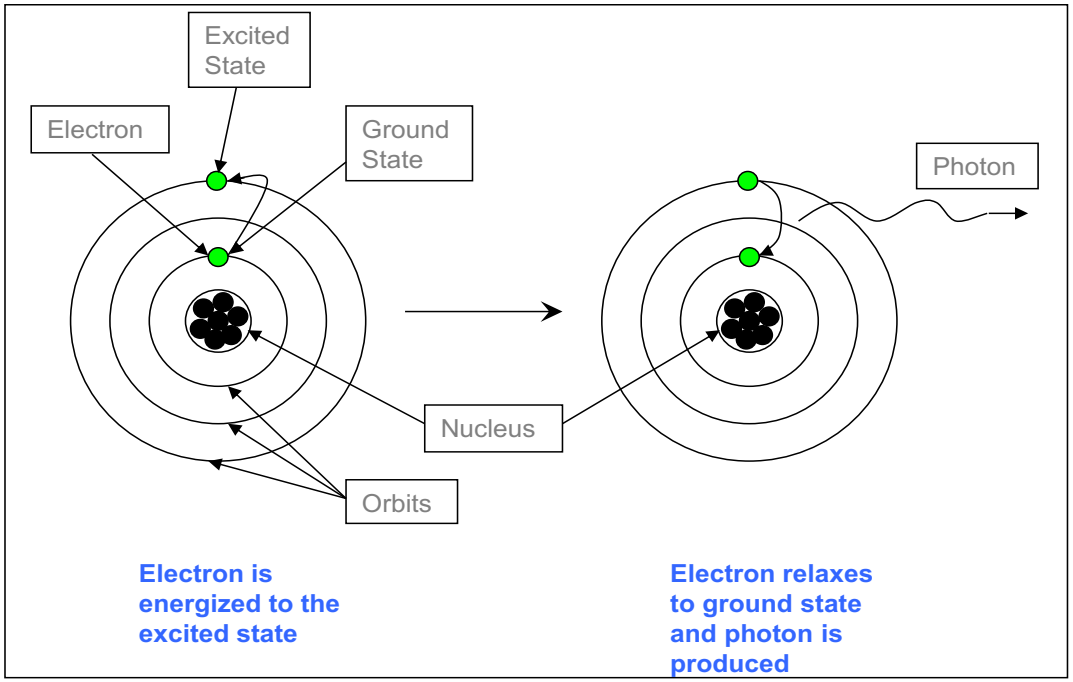
Introduction to Lasers

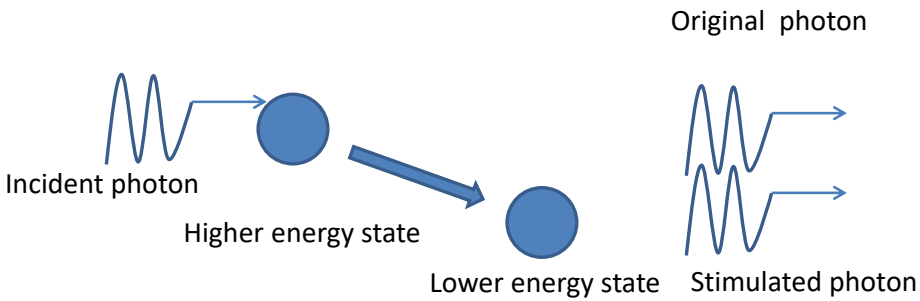
- Lasers are everywhere!
- Some applications
  - Cutting
  - Welding
  - Bending
  - Hardening
  - Cladding
  - 3-D printing
  - Laser Shows Yes!

Laser

- Laser- **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation

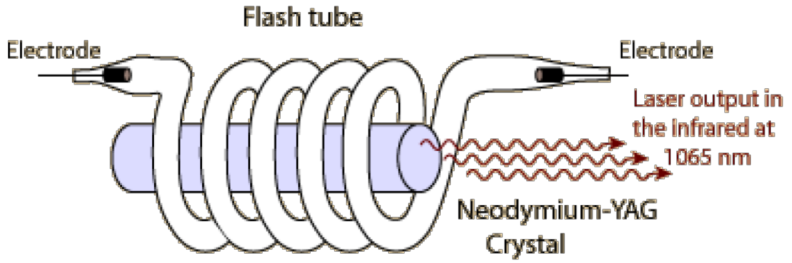
Principle


Excited State
Electron
Ground State
Photon
Nucleus
Orbits
Electron is energized to the excited state
Electron relaxes to ground state and photon is produced


Original photon
Incident photon
Higher energy state
Lower energy state
Stimulated photon

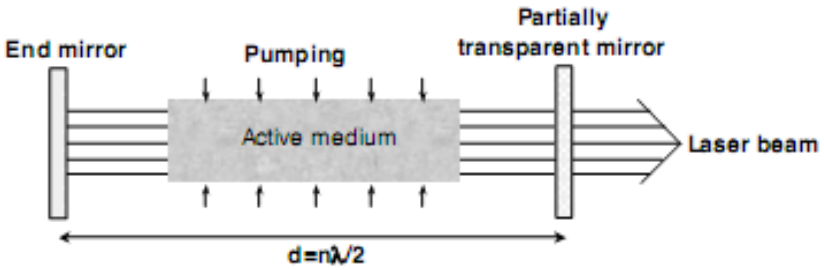
Operating Principle

- Stimulation
  - Source of input power for pumping
  - Mechanical, chemical, electrical or light sources
    - Flash Lamp
    - Electric arc



- Amplification
  - Optical Resonator Construction
    - two, parallel planar (or concave) mirrors
    - Couples part of the optical power back in the active medium
    - Positive feedback -> self-excitation -> oscillation

Optical Resonance



- Optical Resonator Function
  - Photons not aligned are not redirected
  - Amplification occurs only for photons with proper orientation
  - Coherent beam is obtained
- Population Inversion
  - Under equilibrium conditions Boltzmann Equation gives the population at two states:

Optical Resonance (Contd.)

- Under normal condition there are fewer electrons at higher energy states

$$\frac{N_2}{N_1} = e^{-\left(\frac{E_2 - E_1}{KT}\right)}$$

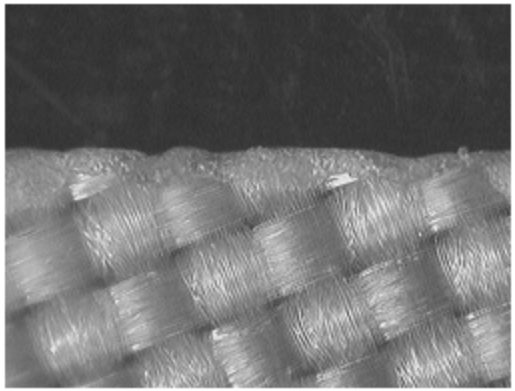
- Population inversion
  - Non equilibrium state where high energy electrons are more to provide stimulated emission

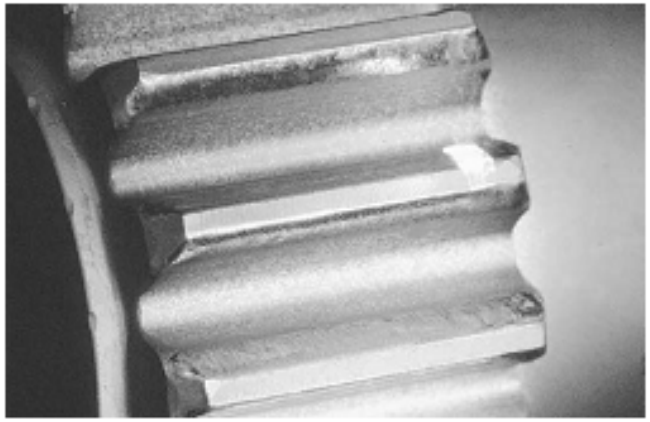
Properties of Laser

- Small divergence
  - Parallel, collimated beam
- High power
  - In continuous (CW) mode: tens, hundreds of watts (e.g., CO2), Few KW (Fiber)
  - Q-switched mode: instantaneous power is enormous (GW)
  - Large spatial power density due to small divergence
- Small spectral width
  - “Monochrome”
  - Large spectral power density
- Polarized
- Possibility of very short pulses
  - ps, fs

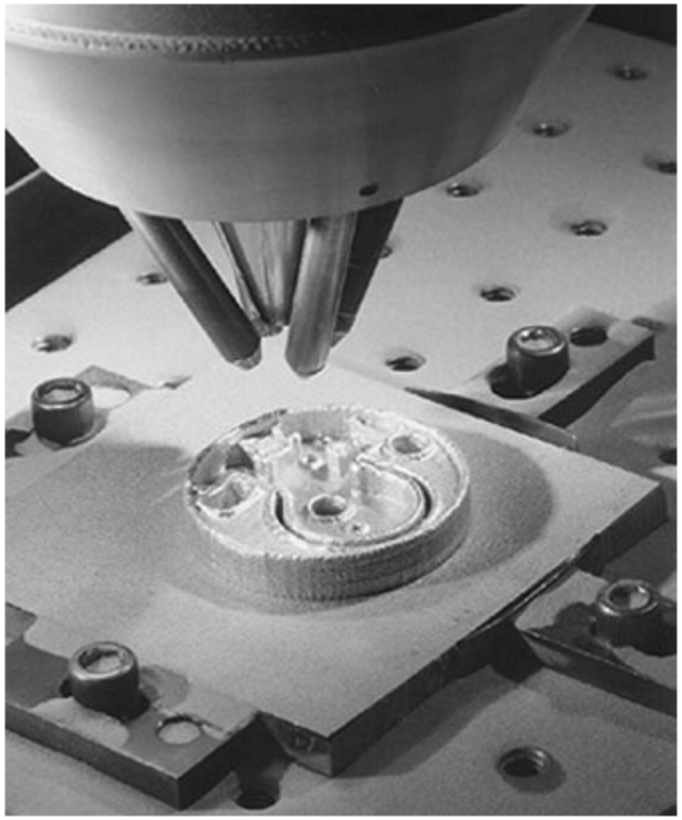
Gillette

Cutting/Hardening

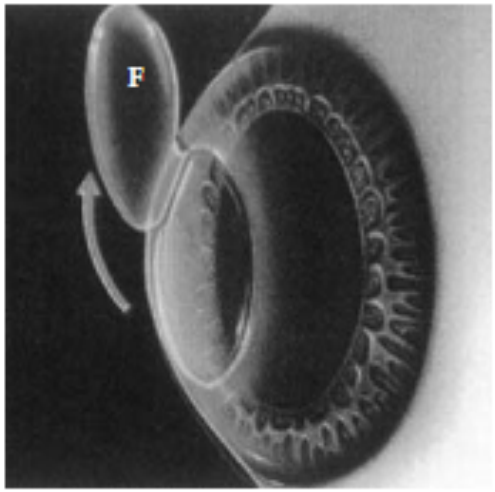


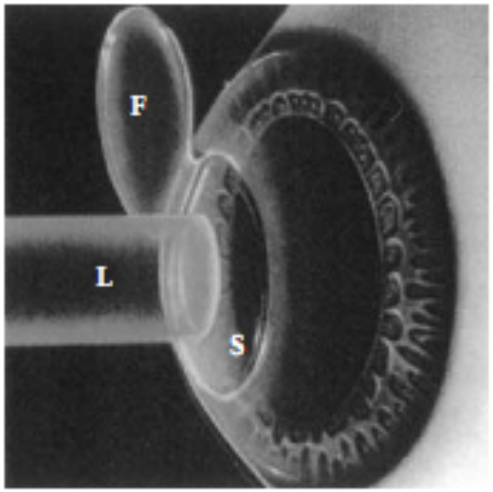


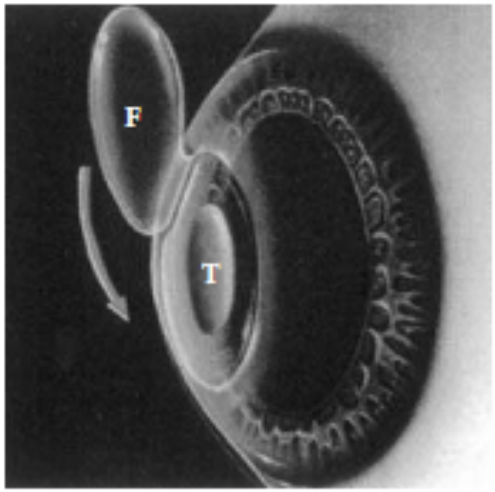
Laser Net Shaping (Sandia)



LASIK







Laser-Summary

- What is needed for laser operation?
  - Stimulated emission
  - Population inversion
  - Pumping
  - Optical resonance
- What are the main properties of laser light?
  - Monochromatic
  - Coherent
  - Large optical power